

Environmental Perturbations, Behavioral Change, and Population Response in a Long-Term Northern Elephant Seal Study

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LONG-TERM GOALS

A major challenge in marine mammal conservation and management is to understand how behavioral responses affect populations. To address this challenge, the National Research Council established the Committee on Characterizing Biologically Significant Marine Mammal Behavior. This committee developed a framework for analyzing the population consequences of acoustic disturbance, or PCAD (NRC 2005). The PCAD framework defines a series of transfer functions which describe how behavioral responses to sound affect life functions, how life functions are linked to vital population rates, and how changes in vital rates cause population change (Fig. 1). The U.S. Navy included the PCAD framework in the U.S. Navy Living Marine Resource Sound Research Requirements, specifically within the “Response to Naval Sounds” requirement #5: *Determine biologically significant behavioral responses from Navy sound sources on individuals representing marine mammal species of concern with respect to ... determining long-term effects of behavioral responses and how individual vital rates may affect the population*. This requirement was given the highest priority under the Navy's requirements.

Implementing the concepts of transfer functions which link behavior to population change, however, requires substantial long-term data on individual animals and population size, and there are few marine mammal populations where quantifying the functions is plausible. Funding from this grant has allowed us to extend and improve a four-decade study of northern elephant seal populations in California, aiming specifically to quantify key linkages within the PCAD model. Since 1968, several thousand individual seals have been tagged and tracked for their lifetimes, and several hundred of those have been weighed or outfitted with telemetry devices in order to document pelagic foraging behavior and body condition. The study has spanned the Pacific Decadal Oscillation and several El Niño events and documented how such environmental fluctuations affect individuals and populations. Recent advances in telemetry and our understanding of foraging behavior and body condition allow us to extend this study into the future with improved methods, and with our current funding we have maintained and advanced a classic long-term study of a vertebrate population.

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OBJECTIVES

Specifically we have collected data to answer two general questions: 1) How closely coupled are short term changes in foraging behavior to adult fecundity and survival? and 2) Does this link vary with environmental perturbations such as the El Niño Southern Oscillation (ENSO) that are known to impact prey availability? Such data are essential for the population modeling effort currently underway by the PCAD Working Group organized by the Office of Naval Research.

These two questions translate into three hypotheses we are testing:

- 1) Adult survival fluctuates with ocean climate, with low survival in the year following ENSO events, and higher survival after non-ENSO years.
- 2) Oceanic climate cycles will impact foraging of pregnant females and weaning weight and survival of pups. Specifically, warming trends (ENSO and “sardine” regimes) will be associated with lowered weaning weights. Survival during the first year at sea will be positively correlated with weaning weight.
- 3) Population growth potential is limited by these ENSO and Decadal (PDO) impacts on foraging and thus animal condition.

APPROACH

These hypotheses will be tested with data gathered through five research activities, all conducted through an ENSO cycle at the Año Nuevo, California, northern elephant seal colony: 1) continue annual censuses of the breeding population; 2) measure adult female body condition; 3) weigh weaned pups to link female condition to reproductive output; 4) continue and expand tag re-sighting to refine survival estimates; 5) continue satellite tracking of adult females to map foraging. Lastly, we have expanded and coordinated resighting efforts at two additional elephant seal colonies in central California in order to examine migration between colonies and assess population trends at larger spatial scales.

We will use data collected from these activities, as well as the legacy data of the past 40 years, to parameterize a Bayesian hierarchical population model, then use elasticity analyses to evaluate the links from ocean conditions to adult survival, nursing resources, weaner size, juvenile survival, and population growth. The results will allow us to explore potential population responses to climatic and other perturbations by building demographic models.

El Niño conditions were present across the equatorial Pacific Ocean in mid-2009 which created increases in sea surface temperatures during the pupping/breeding winter season of 2009/2010. The opposite La Niña conditions persisted through the 2010/2011 winter. Although changes in sea surface temperature were relatively strong, they were short-lived for both years. This is a rare opportunity to extend a dataset that allows us to examine the foraging behavior and demographics of a marine mammal in response to fluctuating environmental conditions. In addition, the long-term seal database spans two prior strong ENSOs, in 1998-99 and 1982-83 (Fielder 2002). Moreover, our results on seals can be placed in a broader context thanks to the coordinating efforts of the Tagging Pacific Predators program (TOPP) which has assembled foraging data from several large marine vertebrates.

WORK COMPLETED

Año Nuevo Breeding and Molting Seasons 2011

Funding from this grant supported multiple components of the field effort associated with the study of both foraging behavior and population demographics of northern elephant seals. As a follow up to the 2009/2010 El Niño event we continued our efforts during the breeding season of 2011 to instrument adult females with electronic tags, collect morphometric measurements on post-partum females and weigh additional weaned pups. Additionally, we recovered instruments deployed on adult females during the 2010 post-molt foraging trip and deployed additional instruments on females for the 2011 post-molt foraging trip. Morphometric measurements were taken on instrumented seals at both the time of deployment and recovery in order to quantify changes in body composition and energy gain while at sea. Body composition and foraging success metrics while at sea will be compared to the previous year of deployments during the El Niño conditions. Foraging metrics include overall mass gain, percent of mass gain, energy gain and rates of all of these calculations, to account for overall trip length.

The data obtained from these foraging trips will allow us to compare at-sea behavior prior to, during and after the 2009/2010 El Niño event and see how shifts in climate regimes affect the foraging-behavior and pup investment of female elephant seals. Previous research has shown weaned pup mass is correlated with such an event. In 2011, we weighed 288 weaned pups, and those weights will be compared to the 236 weights taken during the previous breeding season.

To establish the impact of the El Niño on a larger group of known-age adult females, we collected morphometric measurements, including body mass, on 14 non-instrumented females and 8 instrumented females ages 6-14 years old on postpartum day 5. Day 5 is our normal sampling day, so the new data will provide us with a larger sample to compare to our previous female measurements at day 5. In addition, the effort to ensure known-age females were measured on day 5 required increased tag resight effort compared to other years when age was not a factor. Greater resight effort reduces uncertainty in demographic rate estimates.

Juvenile Resights

Resight effort of juveniles was increased, both on the mainland and on Año Nuevo Island, to a total of 47 days between October 4, 2010 and December 31, 2010. All observed elephant seals with unique identifying flipper tags or dye marks were recorded, but the majority of elephant seals observed during this time period were juveniles or sub adults.

RFID Tag Study

Mark-recapture methods allow researchers to estimate survival and reproductive rates and population growth rates via several well-tested statistical methods. In order to gain the most information, such methods require unique identification of individuals either through naturally occurring marks or via attached tags. To identify individuals, we currently attach external cattle tags in the webbing of hind flippers of northern elephant seals.

However, flipper tags tend to fall off and fade with wear and time. In addition, errors can occur when reading difficult-to-see flipper tags. Tag failure results in underestimates of survival rates and increased uncertainty in survival and reproductive rates. In addition, this population of elephant seals is the focus of an intense effort to understand fasting physiology and at-sea movement and behavior. To that end, it is important to minimize impacts of drugging procedures and carrying of instrumentation

for individual animals. For that reason, identification of an individual throughout its lifetime is doubly important. Lastly, resighting flipper tags may cause behavioral disturbance since reading the tag can require considerable time near the animal.

Implanted radio frequency identification (RFID) tags are used widely in wildlife research and as pet identification devices. RFID tags are very small (about the size of a grain of rice) transponders usually implanted under the skin. They can be read by waving a scanner (about the size of a tennis racket) 12-24 inches away from the animal. RFID tags provide additional benefits to flipper tags in that they are more robust, reader error is eliminated since the tags are read by a computer, and time near the animal can be considerably reduced.

Since RFID tags contain a small airspace that may collapse and permanently damage the tag under pressure, last season we conducted an experiment to determine the tags' abilities to withstand the high and variable pressures associated with the elephant seals' extreme diving behavior. We first bench tested several different size tags. In a pressure chamber, we submitted ten 12.5 mm tags and ten 23 mm tags to pressures greater than the deepest known elephant seal dive. The tags were taken to roughly 2500 psi (equivalent to about 1750 meters depth) and back to 0. The cycle was repeated ten times over a two hour period. The system produces rapid changes in pressure (100 psi over a matter of seconds, then stable for a few seconds, then another rapid change). Afterwards, all tags were scanned. During the post-breeding trip (February-May) RFID tags were incorporated in to external TDR devices carried by 20 individuals. All recovered tags were scanned.

An additional study began in May to determine the best placement for implantation of RFID tags in elephant seals to prevent movement/loss of RFID tags and aid in reading the tag. We attempted to implant larger tags (23 mm long) in or near the tail of two individuals. Smaller tags (12.5 mm long) were injected within the webbing of the rear flippers of 20 individuals and near the tails of 18 adult females anesthetized for other procedures. Immediately after implantation, all tags were scanned and functional. We plan to rescan the implanted tags when the individuals return in January 2012 to determine if the tags moved or fell out during the seven month trip to sea.

RESULTS

Año Nuevo Breeding and Molting Seasons 2011

We deployed 40 sets of data-recording instruments on adult females for the post-molting foraging trip of 2010 (n=20) and the post-breeding foraging trip of 2011 (n=20) and recovered 37 sets of instruments. Each animal carried either a satellite- or GPS-tag and a time-depth recorder and an additional seven animals carried accelerometers. We deployed an additional 20 sets of data-recording instruments for the post-molting foraging trip of 2011 that will be recovered during Jan/Feb of 2012. Increased resight effort allowed us to select all but one known-age female for seals instrumented in 2011, which will allow us to account for any affect of age in our analyses of these animals. .

Females from the PM 2010 foraging trip were relatively successful at sea and appeared to have more successful foraging trips than the previous three years. Females gained an average of 274.8 ± 52.2 kg (SD), approximately 94.9 ± 18.0 % mass gain, over the course of the foraging trip and gained energy at a rate of 16.3 ± 2.1 MJ/day. Energy gain over this foraging trip was the fastest rate of energy gain during the post-molting trip since 2005 (19.2 ± 3.3 MJ/day) and the percent of mass gain was also the greatest observed since 2005 (98.0 ± 21.7). The mean trip length for the PM 2010 foraging trip was

222 \pm 27 days, which was the fifth longest mean trip duration over the past 7 years. Natality for the instrumented females was 86.7 %, the highest observed since 2004 (95.7 %).

Adult females weighed 511.4 \pm 50.1 kg five days post-partum during the 2011 breeding/pupping season (n = 22). That value was slightly higher than measurements taken the previous season. Without correcting for days since weaning, weaned pups weighed 110.2 \pm 22.8 kg (n = 288). Wean mass did not change between years, although masses adjusted for wean date may be higher for 2011 since masses were measured comparatively later and pups were weaned comparatively earlier that season. Long-term analyses of these measurements of fitness will allow us to link the effects of environmental correlates to population demographics and foraging behavior.

Juvenile Resights

Resights between October 4, 2010 and the end of December resulted in a total of 489 unique individuals observed, including 388 identified as juveniles. The majority of animals were seen 1-4 times, although 17 animals were seen 5-9 times each.

RFID Tag Study

All tags were functional after laboratory tests and exposure to normal-to-extreme field conditions. Diving records indicate at least one animal repeatedly dove to 1500 meters.

The needle was too large to efficiently implant larger 23mm tags through thick elephant seal skin. Larger tags would have to be implanted through an additional incision in the skin. Since the goal of additional tagging is to implant tags in many young animals with minimal disturbance, we abandoned implantation of large tags after the first two attempts. We plan to rescan the 20 females implanted with RFID tags this winter when they return to pup to determine if the tags move and/or fall out after implantation. We anticipate the outcome of this final pilot study to be as positive as the other two studies. If the tags are functional, we will begin implanting RFID tags on all animals that are given flipper tags (300-400 animals/y).

IMPACT/APPLICATIONS

Using environmental variability as a proxy for disturbance, the 2009/2010 El Niño provided a rare opportunity to examine how elephant seal foraging behavior and pup provisioning changes with a natural disturbance. We are in the process of statistically comparing the data obtained during the El Niño year to prior and subsequent years. Weaning weight and female morphometric data will be used to inform and parameterize our models of the susceptibility and impact of an acoustic disturbance on elephant seals. These results provide not only the short term response of elephant seals to a change in prey resources but will allow us to quantify how such a reduction impacts their subsequent reproduction and survival. Mark-resight analysis, particularly in relation to mass, will provide us with survival and reproductive rate estimates that can be investigated in the context of the PCAD model. These are all very difficult parameters to otherwise measure in other capital breeders such as mysticetes, and the results from our models may be used to estimate the impact of disturbance on species with similar life history strategies.

RELATED PROJECTS

JIP: Relating Behavior and Life Functions to Populations Level Effects in Marine Mammals: An empirical and modeling effort to develop the PCAD model. Contract JIP 22 07-23.

PUBLICATIONS

Moore, A.M., Arango, H.G., Broquet, G., Edwards, C., Veneziani, M., Powell, B., Foley, D., Doyle, J., Costa, D.P., Robinson, P.W. (in press). The Regional Ocean Modeling System (ROMS) 4-Dimensional Variational Data Assimilation Systems: II - Performance and Application to the California Current System. *Progress in Oceanography*.

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